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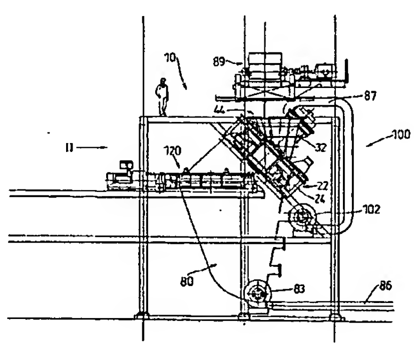
(54) Title: APPARATUS AND METHOD FOR MIXING PARTICULATE MATERIAL WITH A FLUID TO FORM A PUMPABLE SLURRY



(57) Abstract: A feed apparatus (10) for mixing particulate material with a fluid to form a slurry for conveying along a pipeline (86), the feed apparatus including: a housing (22) in which a rotatable disc (12) is movably housed, the housing having an upper wall (28) and a lower wall between which said rotatable disc moves, a material inlet port (43) being provided in the upper wall through which material may be deposited into the rotatable disc, a material outlet port being provided in the lower wall (26) across which material deposited through the material inlet port is moved by the rotatable disc, the outlet port (48) being closed by a sizing grid (66) which only permits material under a predetermined size to pass therethrough, an oversized discharge opening (92) being provided in said lower wall to which oversized material not passing through the sizing grid is moved by said rotatable disc for discharge through said oversized discharge opening, a fluid inlet (46) for introducing fluid for mixing with the particulate material to form said slurry, a sump (80) located beneath said outlet port for receiving slurry discharged through said outlet port, said sump housing a slurry outlet port (82) located in a lower region of the sump through which slurry may be discharged into said pipeline, and a slurry recirculation system (100) connected to the sump and arranged todraw-off slurry from the sump and introduce the drawn-off slurry into said material inlet port.

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APPARATUS AND METHOD FOR MIXING PARTICULATE MATERIAL WITH A FLUID TO FORM A PUMPABLE SLURRY

The present invention relates to a feed apparatus for introducing particulate material into a fluid conduit to enable the particulate material to be conveyed along the fluid conduit in the form of a slurry.

In certain mining operations it is often necessary to convey broken mineral away from the location where it is mined to a remote processing location. In open cast mines, the remote processing station may be several kilometres from the location where the mineral is mined. For certain types of mineral such as, for example, tarsand, it is desirable to convey the won mineral in the form of a slurry along a fluid pipeline to the remote processing location. It is also desirable to convey the won mineral in the form of a slurry having a desired specific gravity, ie. a desired solid to fluid ratio, in order to maximise the rate at which the particulate material is conveyed along the fluid pipeline.

In open cast mining, a large volume of material is processed per hour, eg. 5,000 cubic metres/hour being typical. It is therefore necessary for the feed apparatus to be capable of handling this level of throughput. Typically in order to handle this level of throughput, installations are very large and so tend to be static (ie. not intended to be moved once installed) and are very expensive.

It is a general aim of the present invention to provide a feed apparatus which enables particulate material, such as won material, to be introduced into a fluid pipeline in the form of a slurry of a desired specific gravity.

It is also a general aim to provide such an apparatus which is relatively small but which is able to handle large throughputs of particulate material.

It is also a general aim to provide such an apparatus which is capable of efficiently mixing the fluid and particulate material to provide a consistent slurry mix before introduction into the fluid pipeline.

It is also a general aim to provide such an apparatus, particularly for use in the mining of tarsand, which is capable of reducing lumps contained within the material being deposited into the feed apparatus such that the slurry entering into the fluid pipeline contains a minimum amount of lumps above a predetermined size.

According to one aspect of the present invention there is provided a feed apparatus for mixing particulate material with a fluid to form a slurry for conveying along a pipeline, the feed apparatus including:

a housing in which a particulate material feed member is movably housed, the housing having an upper wall and a lower wall between which said feed member moves, a material inlet port being provided in the upper wall through which material may be deposited into the material feed member,

a material outlet port being provided in the lower wall across which material deposited through the material inlet port is moved by the material feed member, the outlet port being closed by a screen which only permits material under a predetermined size to pass therethrough, an oversized discharge opening being provided in said lower wall to which oversized material not passing through the screen is moved by said material feed member for discharge through said oversized discharge opening,

a fluid inlet for introducing fluid for mixing with the particulate material to form said slurry,

a sump located beneath said outlet port for receiving slurry discharged through said outlet port,

said sump having a slurry outlet port located in a lower region of the sump through which slurry may be discharged into said pipeline, and

a slurry recirculation system connected to the sump and arranged to draw off slurry from the sump and introduce the drawn-off slurry into said material inlet port.

According to another aspect of the present invention there is provided a process for forming a slurry for conveying along a pipeline, the process including mixing said particulate material with a conveying fluid using the apparatus as defined above to form said slurry and subsequently pumping said slurry along said pipeline.

Various aspects of the present invention are hereinafter described with reference to the accompanying drawings, in which:

Figure 1 is a side view of a feed apparatus according to a first embodiment of the invention;

Figure 2 is a part view of the apparatus of Figure 1 as seen in the direction of arrow II;

Figure 3 is a plan view from above of part of the feed apparatus in Figure 1;

Figure 4 is a section along line IV-IV in Figure 3;

Figure 5 is a section along line V-V in Figure 2;

Figure 6 is a plan view from below of the apparatus shown in Figure 1;

Figure 7 is a side view, similar to Figure 1, showing a second embodiment according to the present invention;

Figure 8 is a plan view of the wheel casing, without the wheel, of the apparatus shown in Figure 7;

Figure 9 is a side view of the casing shown in Figure 8;

Figure 10 is an enlarged part section along X-X in Figure 9;

Figure 11 is a perspective view from below of the casing shown in Figure 8;

Figure 12 is an enlarged part plan view showing a grid section;

Figure 13 is a part sectional view taken along line XII-XII in Figure 13;

A feed apparatus 10 according to a first embodiment of the invention is shown in Figure 1. The apparatus 10 is described below for mixing tarsand with a fluid (usually water) to form a slurry. It will be appreciated, however, that the apparatus may be used for forming other types of particulate materials into a slurry.

The feed apparatus 10 includes a housing or casing 22 in which is movably housed a material feed member, preferably in the form of a rotatable wheel or disc 12 (Figure 4). In a typical installation, for use in an open cast mine, the outer diameter of the disc 12 may be in the region of 9 metres. This would enable a throughput of about 5,000 cubic metres/hour to be achieved.

The disc 12 is provided with a row of tube-like pockets 14 arranged in an annulus which is centred upon the axis of rotation of the disc 12. The disc 12, at least in the region of the row of pockets 14, has a pair of planar sides 16, 18 which are spaced laterally from one another. Each pocket 14 has opposed open ends; one open end being located in one planar side 16 and the other open end being located in the other planar side 18.

Preferably, the row of pockets 14 is defined by an annular slot in the disc 12 and a series of circumferentially spaced radial vanes 20 which divide the slot into individual pockets 14.

Rotation of the disc 12 about its axis causes the pockets 14 to be moved in succession around the axis of rotation. The planar sides 16, 18 are arranged perpendicularly to the axis of rotation so that during rotation of the disc 12, the planar sides 16, 18 are moved in a direction parallel to the planes containing those sides 16, 18.

The terminal edges of the vanes 20 are preferably co-planar with the sides 16, 18.

The disc 12 is rotatably housed within a sleeve-like casing 22 having a cylindrical wall 24. The casing 22 is closed off at its bottom end by a lower end wall 26 and closed off at its top end by an upper end wall 28.

The disc 12 is mounted on a drive shaft 30 which is rotatably mounted within a cylindrical housing 32. The lower end of housing 32 is mounted on the top wall 28, and a drive motor 34 is mounted upon the upper end of the housing 32. The motor 34 serves to rotate the disc 12 within the casing 22, typically at about 10-12 rpm. The motor 34 is preferably adjustable to permit variation of the speed or rotation of the disc 12.

The upper wall 28 is provided with a material inlet port 43 through which won tarsand may be deposited into the pockets 14.

A hopper 44 is preferably attached to the upper wall 28 in order to facilitate feeding of tarsand through the inlet port 43.

As best seen in Figures 2 and 6, the lower wall 26 is provided with a material outlet port 48 which extends circumferentially about the axis of rotation of disc 12. The outlet port 48 is closed off by a sizing grid 66 which acts to permit material below a predetermined size ('undersized material') to pass through.

Lumps of material of a size greater than the predetermined size ('oversized material') are retained by the sizing grid 66 and are not allowed to pass through the outlet port 48.

The circumferential extent of the outlet port 48 is preferably as great as possible in order to enable the desired amount of throughput of material to pass therethrough quickly in order to avoid undesirable build up of material in the hopper 44 ie. it is desirable for material to be removed from the hopper 44 at least as fast as material is deposited into it.

Ideally as seen in Figures 2 and 6, the port 48 extends circumferentially for a large proportion of the lower wall 26, for example for about 180°. It may however extend circumferentially for more or less than this amount.

The lower wall 26 is also provided with an oversized material discharge opening 92 through which oversized material separated out by the grid 66 is discharged.

In use, the disc 12 is preferably continuously rotated (clockwise as seen in Figure 2) in order to move each pocket 14 in succession from the inlet port 43, across the grid 66, to the discharge opening 92 and back to the inlet port 43.

The casing 22 is preferably inclined so that the axis of rotation of the disc 12 is inclined at an acute angle to the horizontal so that in use the casing 22 has an upper portion 22_u and a lower portion 22_ℓ. The inclination of the axis of rotation is preferably about 45°.

As seen in Figures 4 and 5, the vanes 20 are preferably inclined relative to the direction of movement of the disc 12.

Inclination of the vanes 20 is preferably adopted in order to avoid problems with jamming caused by a vane 20 and the top wall 28 in the vicinity of the downstream end wall of the port 43 (in the direction of rotation of the disc)

attempting to grip and shear lumps of material protruding out of the top of a pocket as it is moved under the top wall 28.

By inclining the vanes 20 such that the upper edge of the vane 20 trails behind the lower edge of the vane (in the direction of rotation), lumps of material protruding out of the pocket 14 are encouraged to roll over the edge of the vane and into the next pocket. The degree of angle of inclination of the vane 20 is chosen bearing this required function in mind. In addition, excess material in a pocket 14 is encouraged to spill over to the succeeding pocket 14. This section helps to encourage disturbance or agitation of the material and so help in breaking down lumps. The angle of inclination is chosen to be about 30° when the inclination of the axis of rotation of disc 12 is about 45°.

The sizing grid 66 preferably has a side face 68 which is co-planar with the inner face of the lower wall 26.

Accordingly, the vane edges slidingly move over the side face 68 and act as scrapper blocks to clear debris therefrom so as to keep the sizing grid 66 clear.

A fluid inlet port 46 is provided on the upper wall 28, preferably at a location opposed to the outlet port 48 so that fluid discharged from port 46 passes through the outlet port 48 via pockets 14. Preferably the fluid port 46 is located opposite the downstream end of the outlet port 48 (in the direction of rotation of disc 12) so as to act to wash the pockets 14 and oversized material contained therein clear of undersized material.

A large capacity sump 80 is located beneath casing 22 and is arranged to receive undersized material being discharged from the outlet port 48. Preferably the upper region of the sump 80 is secured to a flange 48a

surrounding the outlet port 46 so that the casing 22 and sump 80 thereby define a closed container.

A slurry outlet port 82 is located at the bottom of the sump 80. A pump 83, preferably a vaned centrifugal pump, is connected to the port 82 and is arranged to pump slurry from the sump 80 and into a pipeline 86 for transport to a remote location.

A slurry recirculation system 100 is provided for drawing slurry from the sump 80 and re-introducing it into the inlet port 43 via a pipe 87 for mixing with the won tarsand as it is being deposited into the hopper 44 from conveyor 89.

The action of introducing the recirculated slurry into inlet port 43 assists in the breaking down of lumps of tarsand being deposited into the hopper 44 and facilitates passage of undersized material through the grid 66.

The recirculation system 100 includes a pump 102, preferably a vaned centrifugal pump, and the mechanical action of the pump 102 also assists in breaking down further the undersized material, and then improving the consistency of the slurry.

Preferably a mineral reducer 120, for example a twin roll mineral breaker or crusher, is located beneath the oversized opening 92 to receive the oversized material being discharged therefrom.

As indicated above the mineral reducer 120 discharges the broken down oversized material into the sump 80. Accordingly, all the tarsand being deposited into the hopper 44 is utilised for mixing with fluid entering via inlet port 46 to form a slurry. This helps to ensure consistency of the specific gravity of the slurry (since solid material is not being discharged

separately from the apparatus) and also ensures that there is no wastage of material.

Preferably the mineral reducer 120 includes a closed chute 122 which is connected to casing 22 and the mineral reducer 120 for directing oversized material from the outlet 92 into the mineral reducer 120. Also, the lower portion of the mineral reducer 120 is preferably connected to the sump 80 such that the interior of the mineral reducer 120, the chute 122, casing 22 and the sump 80 define an enclosed container.

The recirculation system 100 is preferably arranged to drain slurry from the sump 80 at a location above the slurry outlet port 82.

Preferably both pumps 83, 102 are high capacity pumps (preferably of the same capacity) capable of conveying slurry at a rate of between 3 to 5 metres/second. Under steady state conditions, in use, the level of slurry contained in the sump 80 needs to be higher than the location at which pump 102 draws slurry from the sump 80 in order to maintain the recirculation function. The level is preferably determined such that there is sufficient slurry in the sump to prevent the pumps 83 or 102 being starved of slurry for a predetermined time, say 15 seconds, after interruption of supply of material to the hopper 44.

In addition the specific gravity of the slurry may increase progressively toward the bottom of the sump 80.

Accordingly, the height of the location from which pump 102 draws slurry from the sump 80 may affect continuous operation of the apparatus and/or the consistency of the specific gravity of the slurry being drawn from the sump by pump 83.

It is therefore preferable to make the height of the location at which pump 102 draws slurry from the sump 80 adjustable in order to enable the apparatus to be set-up on site to operate at a desired steady state condition. This may conveniently be done by providing the sump housing with a plurality of outlet ports 88 located at different heights for selective connection to pump 102.

Preferably a specific gravity monitor means is located adjacent to the bottom of the sump 80 in order to monitor the specific gravity of the slurry. For tarsand, a desired specific gravity is about 1.55.

The specific gravity of the slurry is determined by the relative volumes per unit time of tarsand being deposited into the hopper and of fluid being introduced by the fluid inlet port 46. Preferably the relative proportions are set by reference to the slurry monitor in order to achieve the desired specific gravity.

In addition the level of slurry contained in sump 80 (when pump 102 is operating at a constant flow rate) is determined by the volume of slurry per unit from being drawn out of the sump 80 by pump 83 compared to the combined volumes per unit time of the tarsand deposited in hopper 44 and fluid introduced by inlet port 46.

Accordingly, when setting up the apparatus for use, the sump 80 is permitted to fill to a desired level before operating pump 83. The pump 83, material feed for depositing the tarsand into hopper 44 and the supply of fluid to inlet port 46 are then operated to ensure that a steady state is achieved whereat the level of slurry in sump 80 remains substantially constant.

It is envisaged that the fluid (which is normally water) introduced through inlet port 46 and possibly the casing 22 may be heated (to a temperature of say 40-70°C) in order to render the tar content of the tarsand fluid.

In operation under winter conditions, tarsand typically includes blocks of ice. The combination of the mechanical action of the apparatus on the tarsand as it passes through the apparatus and the elevated temperature assists in breaking down the blocks of ice to undersized dimensions and so enables a slurry to be produced having a consistent specific gravity and an even temperature throughout.

A second embodiment according to the present invention is illustrated in Figures 7 to 13 wherein parts similar to those in Figures 1 to 6 are designated by the same reference numerals.

In the second embodiment 200, the recirculation pump 102 is located at the lower region of the sump 80 at substantially the same level as pump 83.

A sizing grid 210 is located within the sump 80 to extend downwardly from the lower portion of the casing 22 to the bottom wall 80b of the sump 80.

The sizing grid 210, in effect, divides the interior of the sump 80 into two regions or zones; viz region A and region B.

The inlet to pump 83 is located in region B and so all solid particulate material reaching pump 83 will have passed through grid 210 and so the slurry being pumped by pump 83 will contain lumps of material which are up to a desired maximum size. Preferably for a tarsand application, the sizing grid 210 is sized so as to permit particulate material up to a lump size of about 50-100mm to pass therethrough.

Particulate material of a size greater that the size permitted to pass through the sizing grid 210 is directed by the grid and sump sides to the recirculating pump 102 to be broken down by the mechanical action of the recirculation system 100 (in particular pump 102). This action of reducing the size of lumps separated by the sizing grid 210 is repeated by the recirculation system 100 until the lump size is reduced the permit it to pass through grid 210.

It will be noted that all solid material exiting directly from the casing 22 or from the mineral breaker 120 is deposited into zone A in the sump 80 and so is acted upon by the grid 210.

The sump 80 having a grid 210 and pumps 83, 102 arranged as described above may be incorporated into the first embodiment described with reference to Figures 1 to 6.

In the second embodiment 200, the outlet port 48 is divided into two regions; a primary grid region 250 which is located directly beneath the feed hopper 44 and a secondary grid region 251 whereat fluid inlet port 46 is located. As seen in Figure 8, the outlet port 48 extends circumferentially for about 120° and thereby provides a large opening area through which particulate material and slurry introduced by pipe 87 of the recirculation system may pass quickly.

The primary grid region 250 which is located directly beneath the feed hopper 44 is preferably made up of a plurality of grid sections 300 each of which is preferably seated upon radial strengthening ribs 310 of casing 22. Preferably each grid section 300 is adapted to be removably mounted in the casing 22 by access from above via pockets 14 of wheel 12.

As illustrated in Figures 12 and 13, each section 300 preferably comprises two section halves 320 each having opposed side ribs 321 between which a plurality of cross ribs 322 extend to define grid openings 323.

Outer side ribs 321 of each section half 320 are seated upon a seat 311 formed on a strengthening rib 310 and is located beneath a top plate 325 which define the bottom wall 26 of the casing 22. Accordingly, each outer side rib 321 is constrained against movement in an upwardly/downwards direction but is free to move side to side.

As indicated in Figure 12, inner side ribs 321 of adjacent section halves 320 are secured together by securing means, preferably in the form of bolts 340. Removal of bolts 340 enables the section halves 320 to be moved apart slightly and thereafter enables each half to be tilted upwardly and so be removed from the casing 22 via a pocket 14 of the wheel 12.

Each grid section half 320 may be fabricated from rolled metal or may be cast in one piece from a suitable metal.

Extending between adjacent radial ribs 310 there are preferably provided support ribs 360 having seats 361 upon which the outer end innermost ribs 322 are seated. Accordingly each section 300 is fully supported around its periphery.

CLAIMS

1. A feed apparatus for mixing particulate material with a fluid to form a slurry for conveying along a pipeline, the feed apparatus including:

a housing in which a particulate material feed member is movably housed, the housing having an upper wall and a lower wall between which said feed member moves, a material inlet port being provided in the upper wall through which material may be deposited into the material feed member,

a material outlet port being provided in the lower wall across which material deposited through the material inlet port is moved by the material feed member, the outlet port being closed by a screen which only permits material under a predetermined size to pass therethrough, an oversized discharge opening being provided in said lower wall to which oversized material not passing through the screen is moved by said material feed member for discharge through said oversized discharge opening,

a fluid inlet for introducing fluid for mixing with the particulate material to form said slurry,

a sump located beneath said outlet port for receiving slurry discharged through said outlet port,

said sump housing a slurry outlet port located in a lower region of the sump through which slurry may be discharged into said pipeline, and

a slurry recirculation system connected to the sump and arranged to draw off slurry from the sump and introduce the drawn-off slurry into said material inlet port.

2. A feed apparatus according to Claim 1 including a mineral reducer arranged to receive said oversized material being discharged from said oversized discharge opening, the mineral reducer communicating with said sump so as to discharge material reduced thereby into the sump.

3. A feed apparatus according to Claim 1 or 2 wherein the feed member is in the form of a disc which is rotatable about a central axis and includes a row of open ended pockets in the form of an annulus centred on said axis.

4. A feed apparatus according to Claim 3 wherein the central axis is inclined at an acute angle relative to the horizontal.

5. A feed apparatus according to Claim 3 or 4 wherein the material outlet port has a circumferential extent around said central axis in the range between about 45° to 180°.

6. A feed apparatus according to any preceding claim wherein the recirculation system include a vaned centrifugal pump.

7. A feed apparatus according to any preceding claim wherein the recirculation system is arranged to draw-off slurry from the sump at a location above said slurry outlet port.

8. A feed apparatus according to Claim 7 wherein the height of the location above said slurry outlet port at which slurry is drawn-off by said recirculation system is adjustable.

9. A feed apparatus according to any preceding claim including a specific gravity monitoring means for monitoring the specific gravity of slurry located in the sump.

10. A feed apparatus substantially as herein described with reference to and as illustrated in the accompanying drawings.

11. A process for forming a slurry for conveying particulate material along a pipeline, the process including mixing said particulate material with

a conveying fluid using a feed apparatus according to any preceding claim to form said slurry and subsequently pumping said slurry along said pipeline.

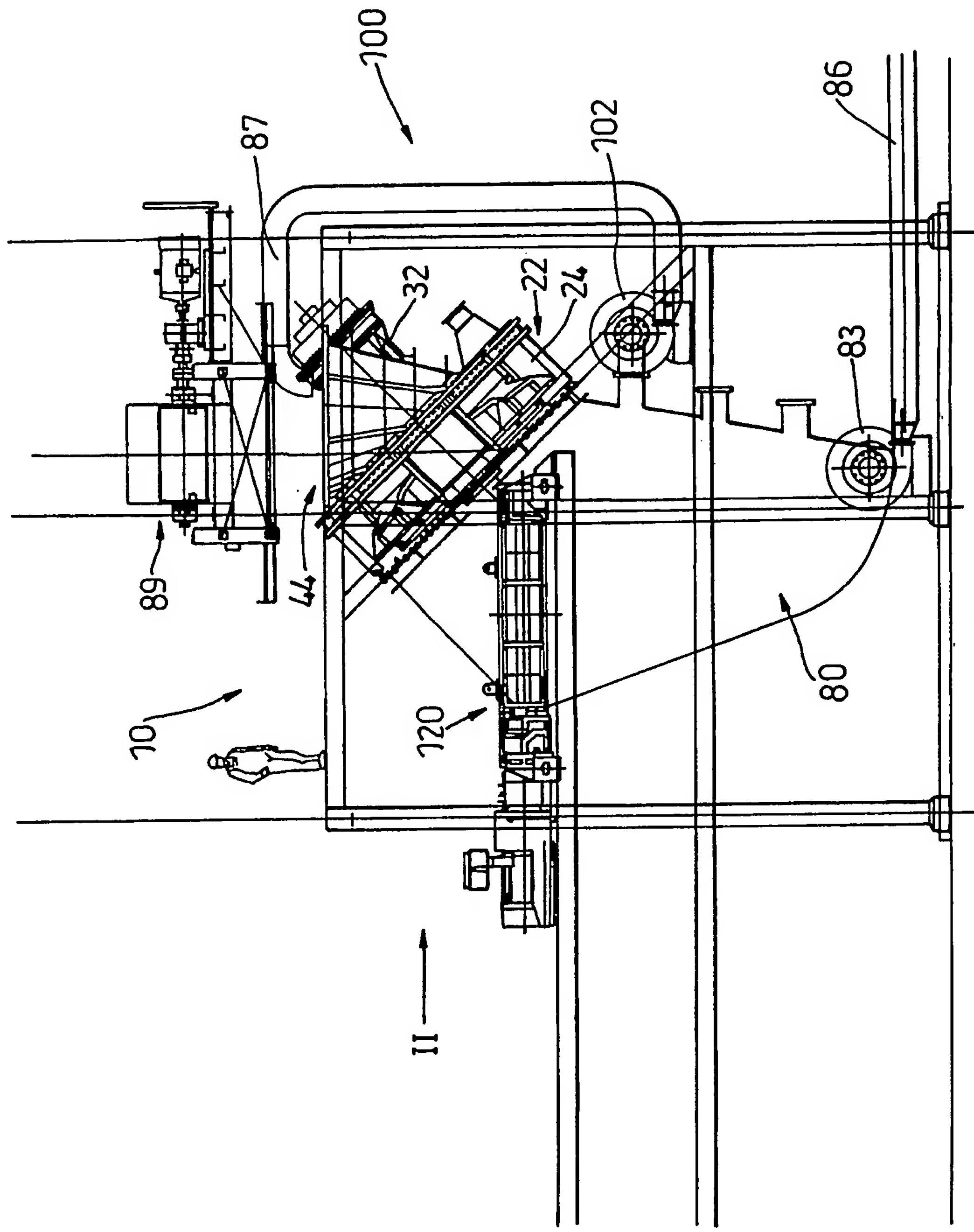

Fig. 1

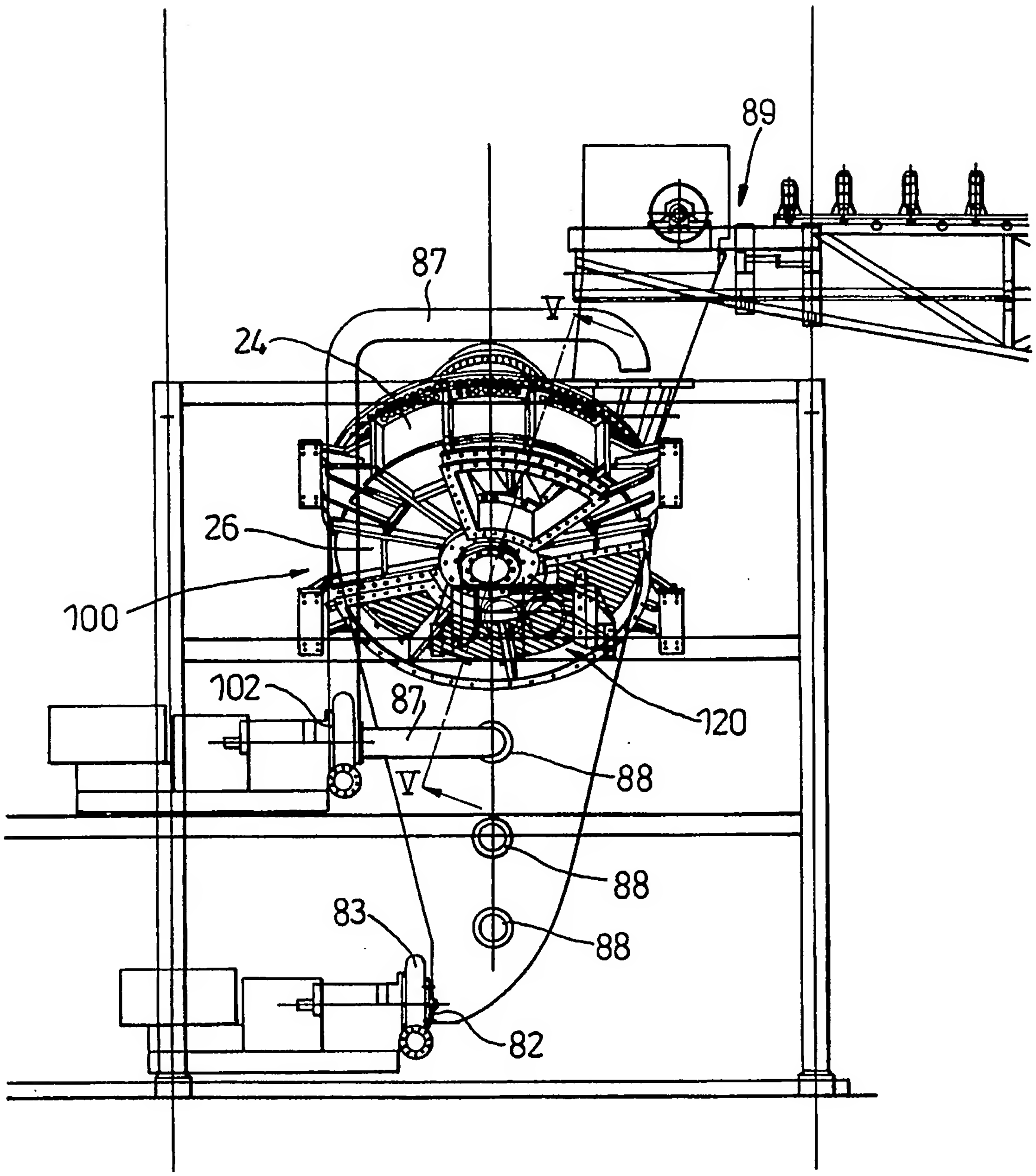

Fig. 2

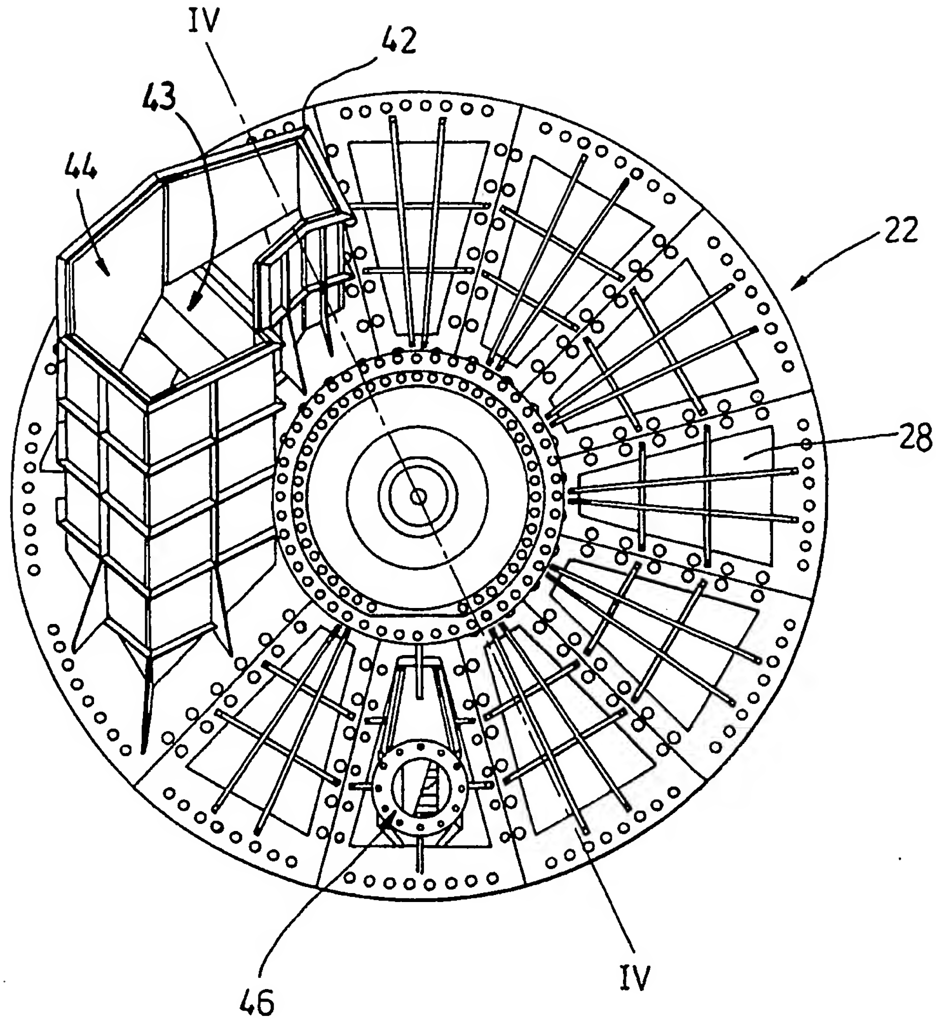

Fig. 3

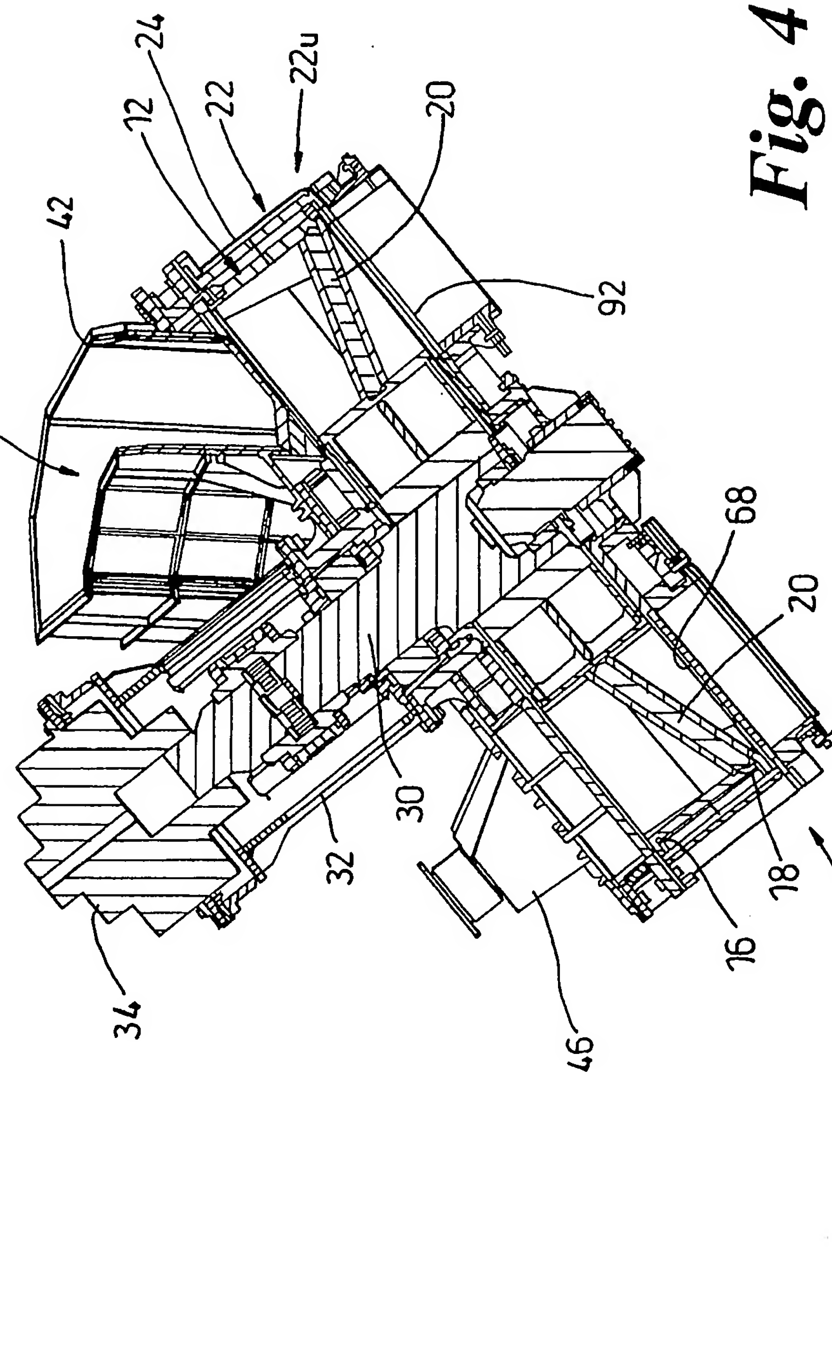

Fig. 4

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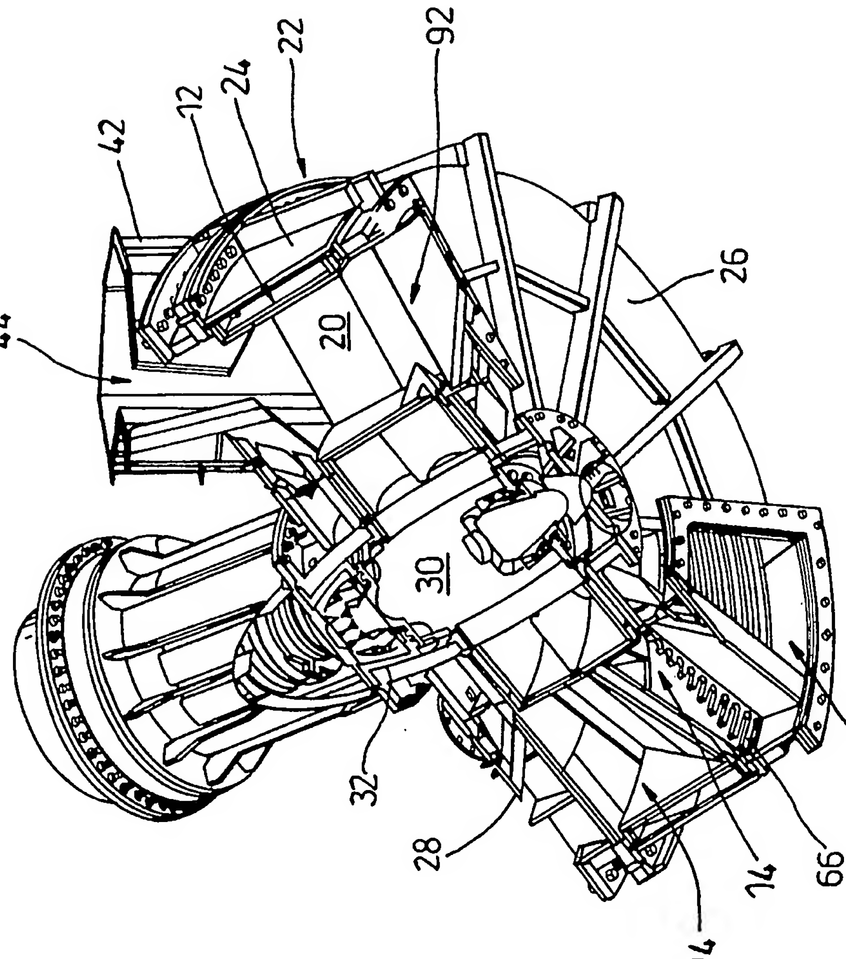

Fig. 5

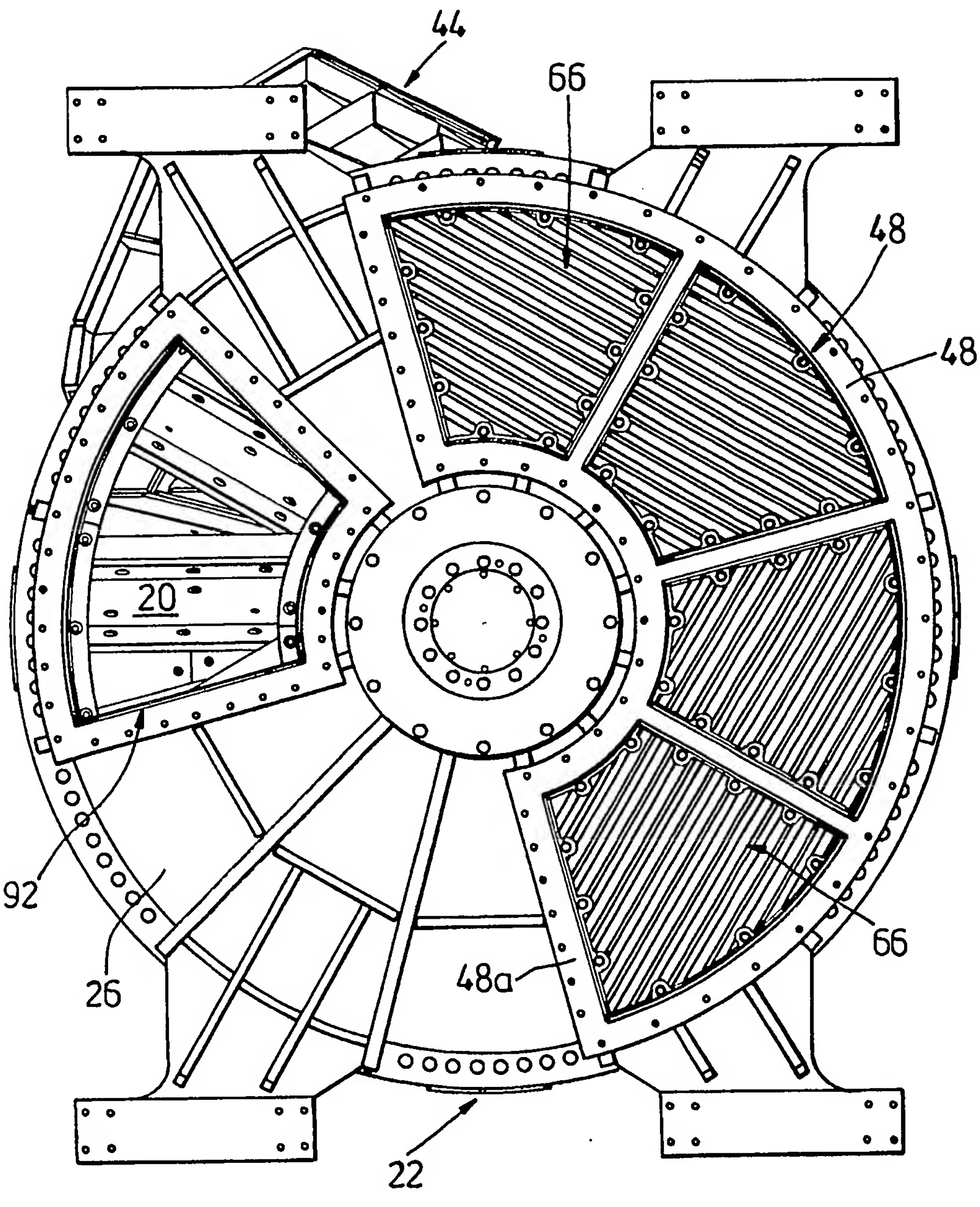

Fig. 6

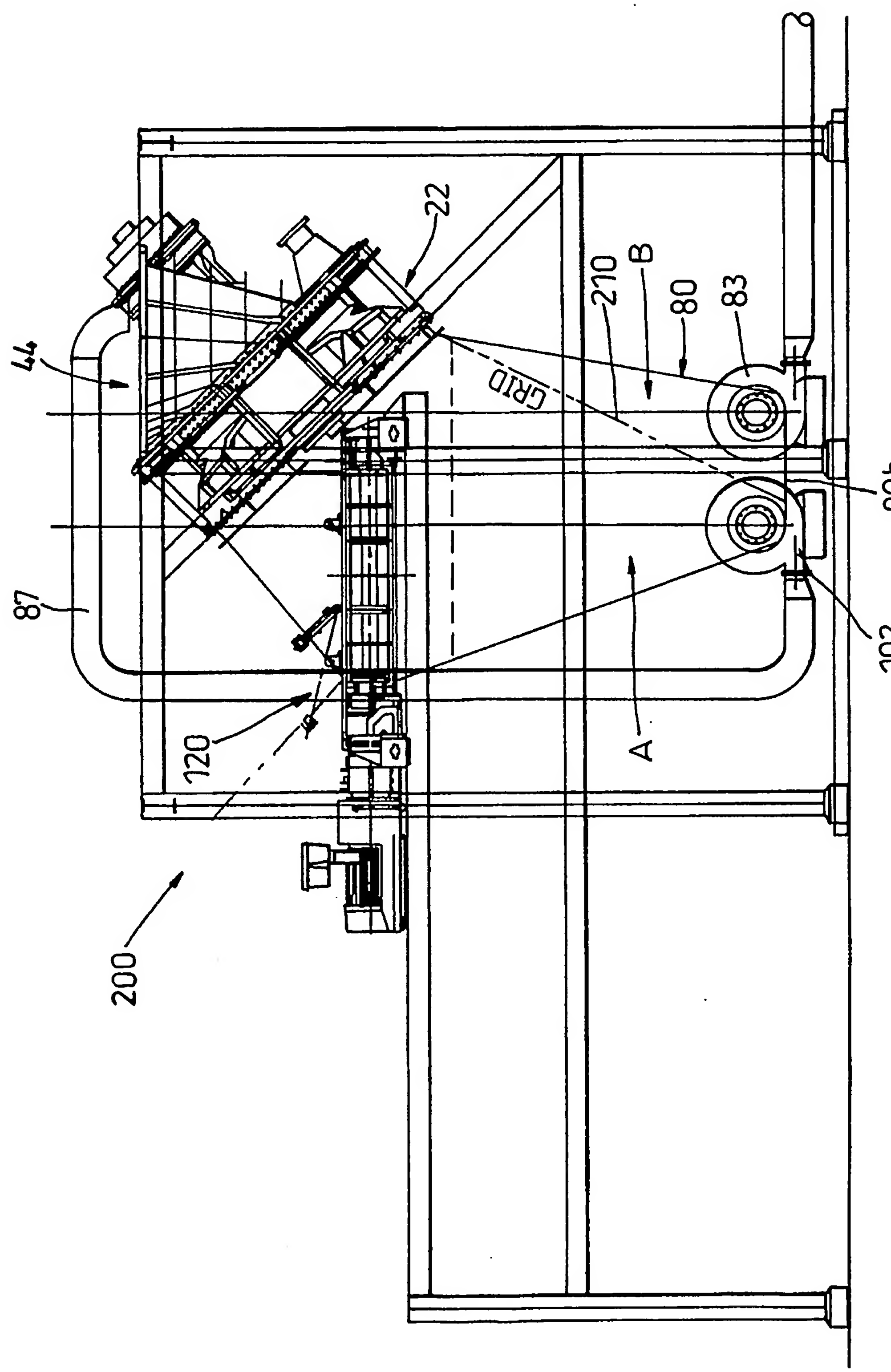

Fig. 7

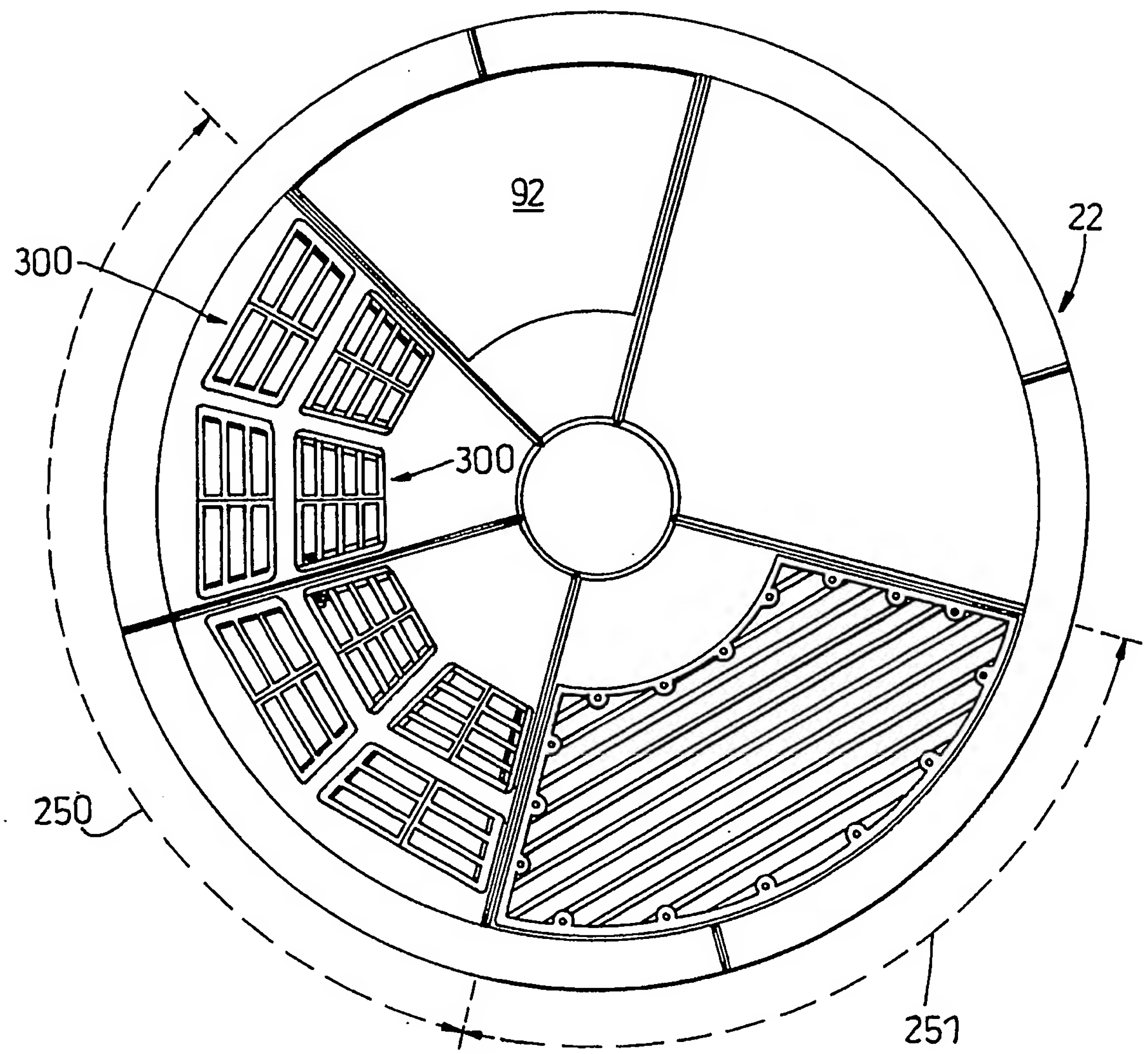

Fig. 8

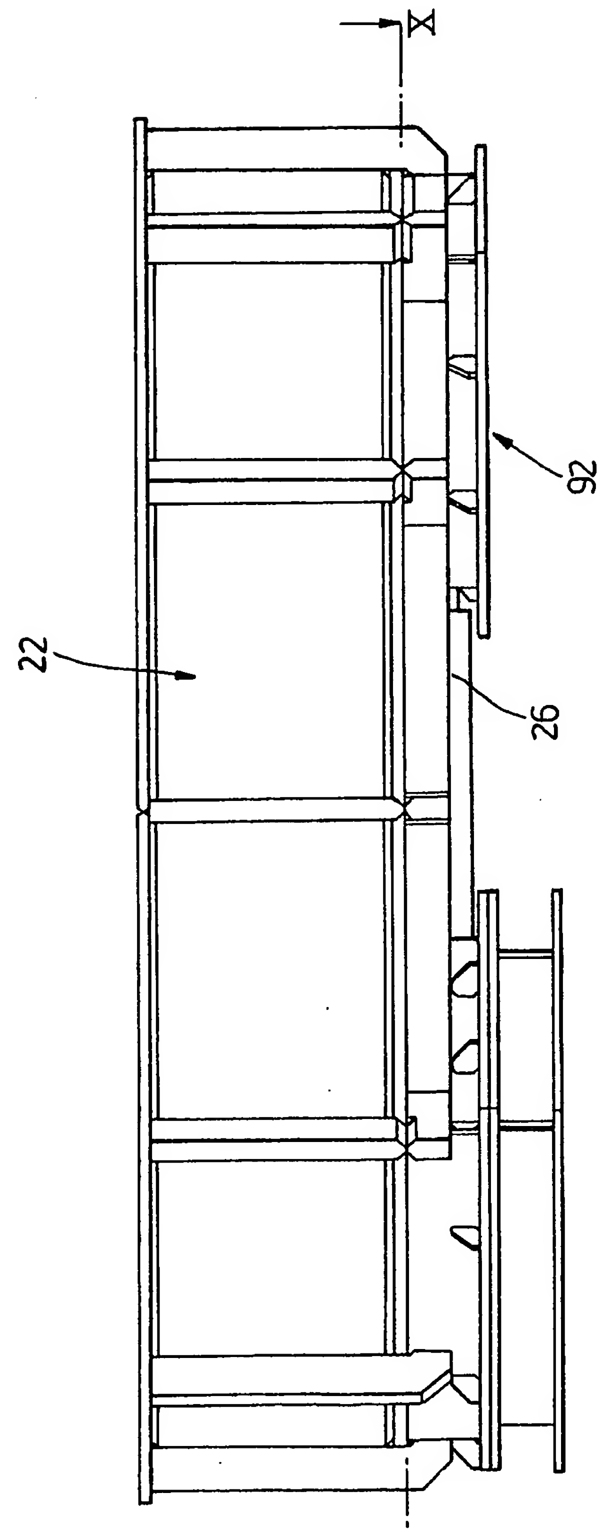

Fig. 9

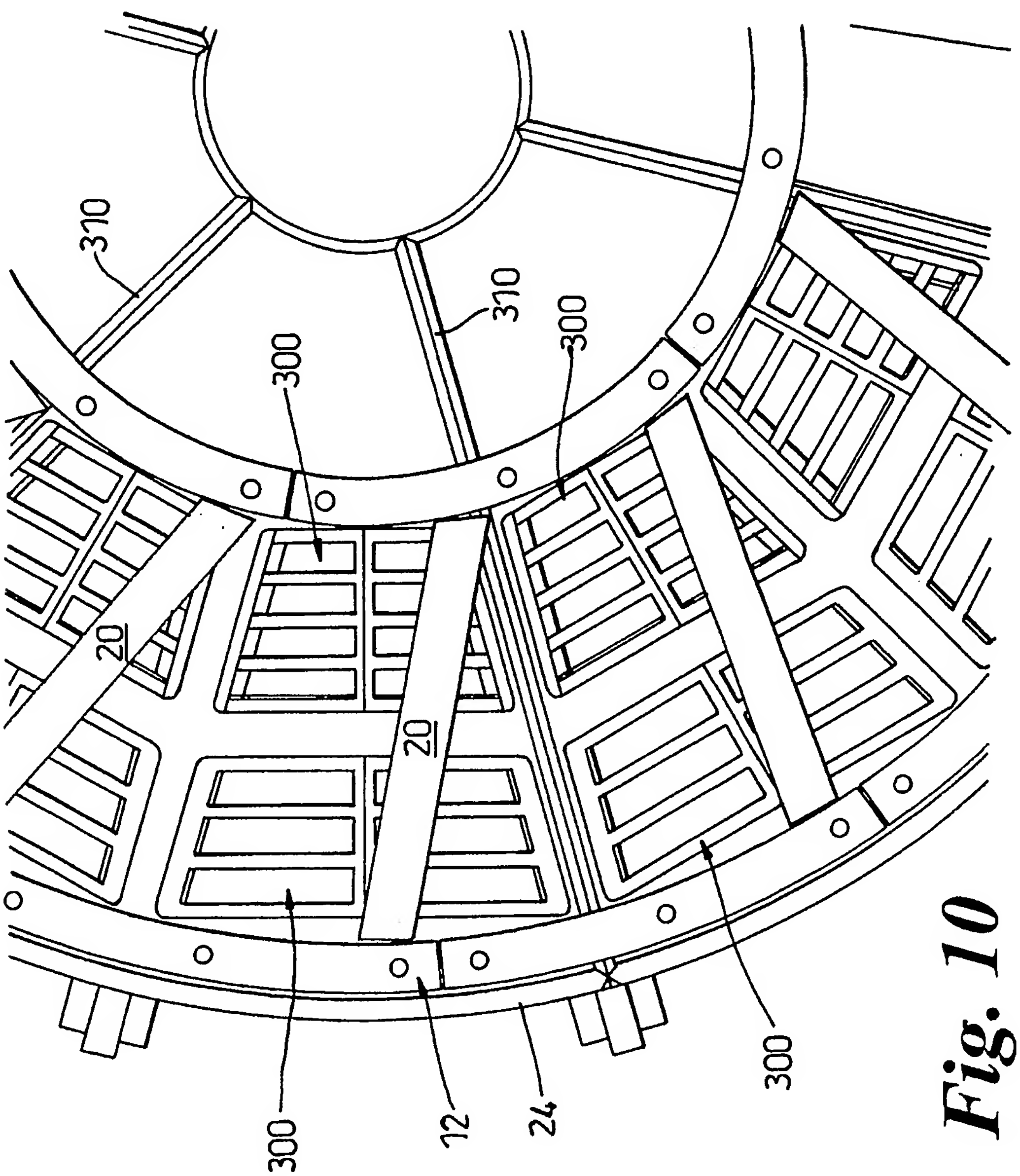

Fig. 10

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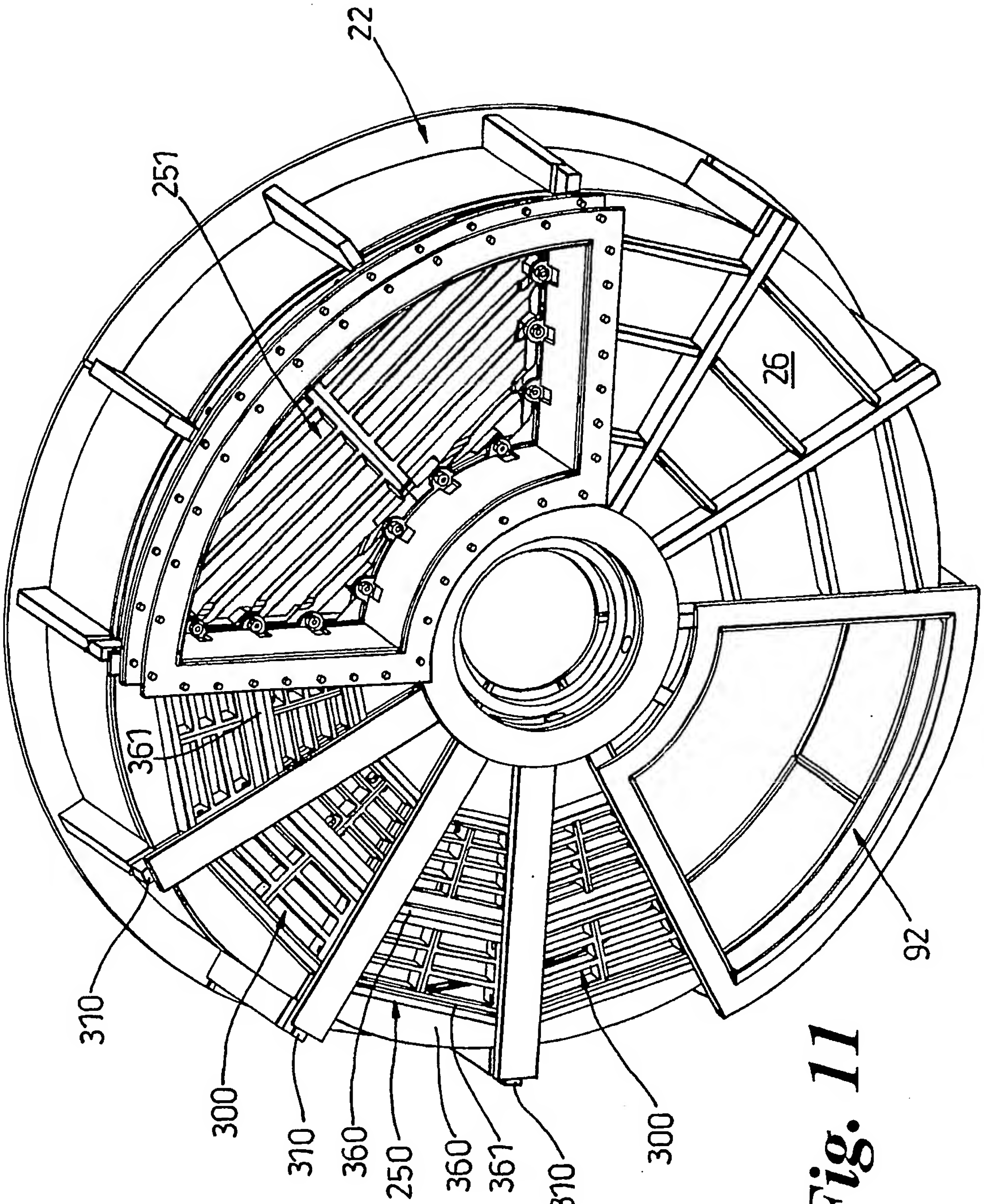

Fig. 11

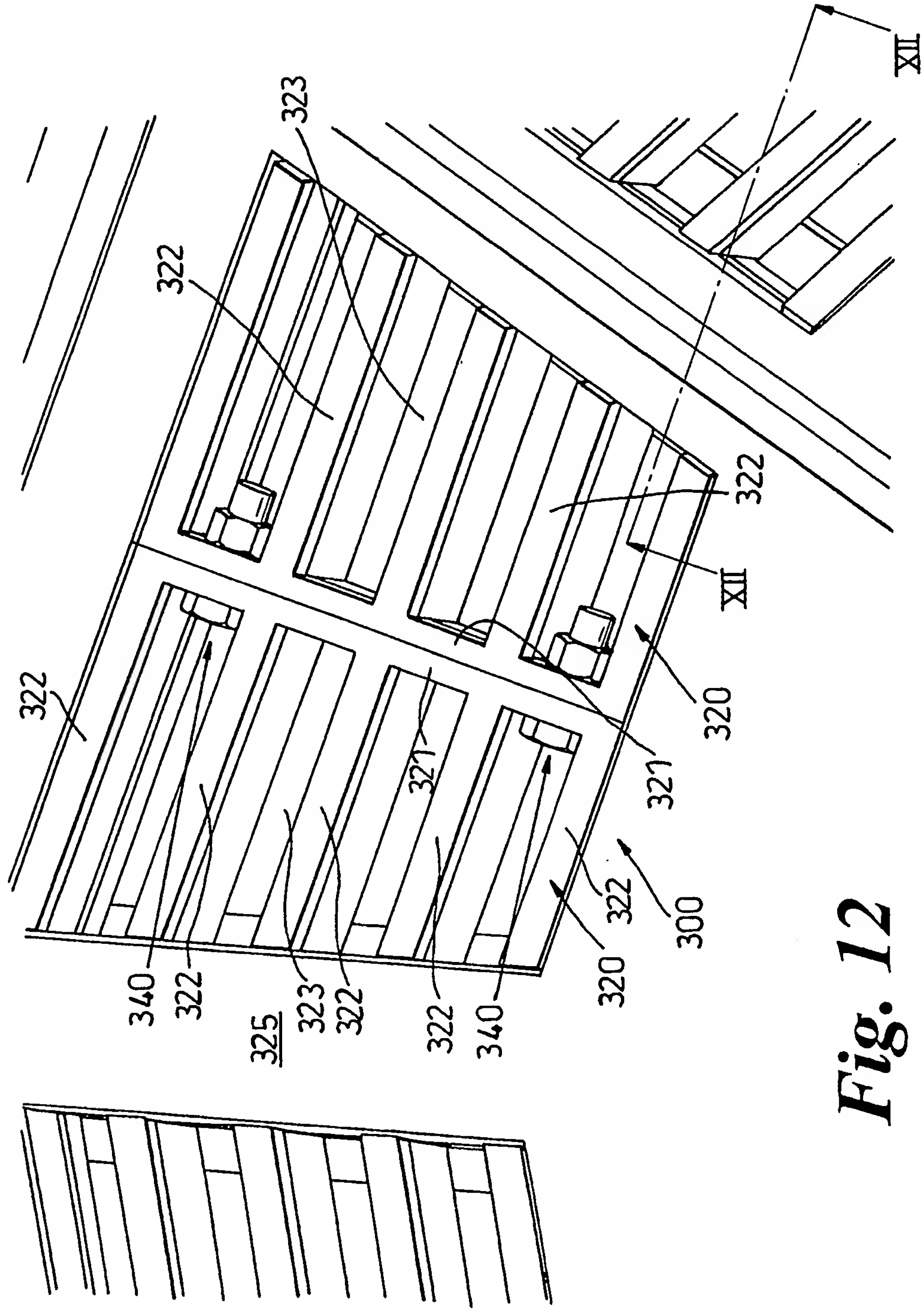
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Fig. 12

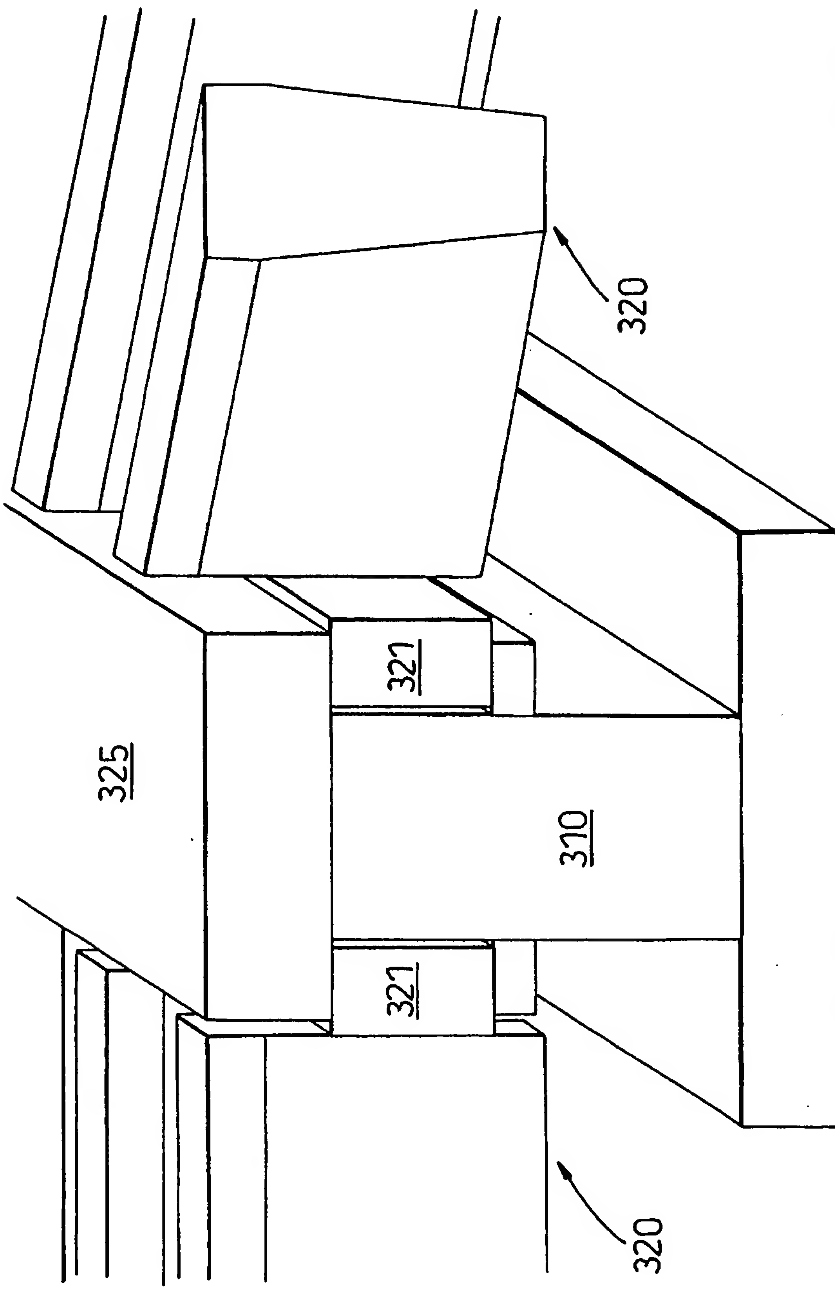

Fig. 13

INTERNATIONAL SEARCH REPORT

ational Application No
/GB2004/002756

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B01F3/12 B01F5/10 B01F15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B01F E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	CA 2 227 667 A (CYMERMAN G ET AL) 22 July 1999 (1999-07-22) page 7, line 1 - page 9, line 18 abstract; claims 1-7; figure 1 ----- -/--	1-11

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Date of the actual completion of the international search	Date of mailing of the international search report
6 October 2004	14/10/2004
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Brunold, A

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